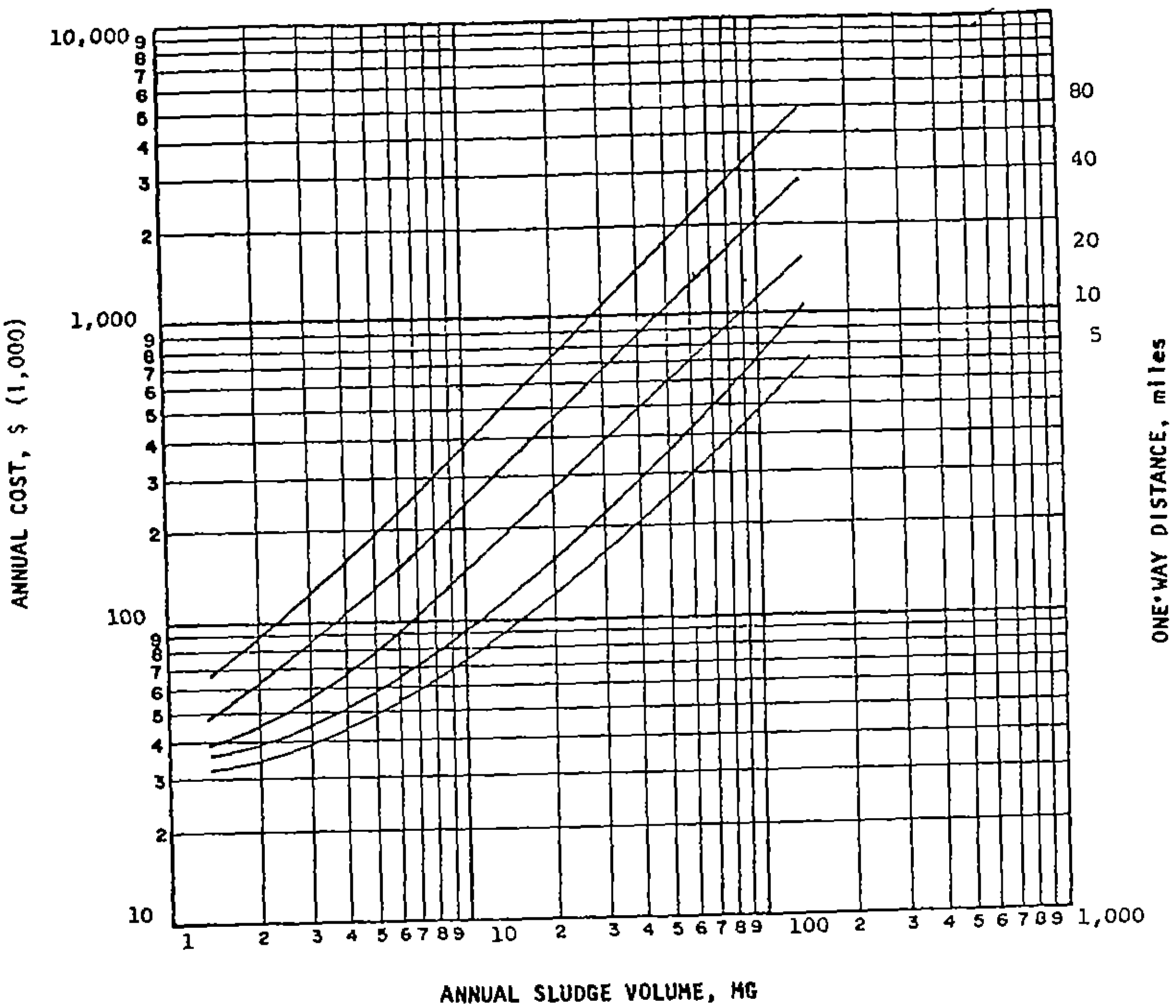
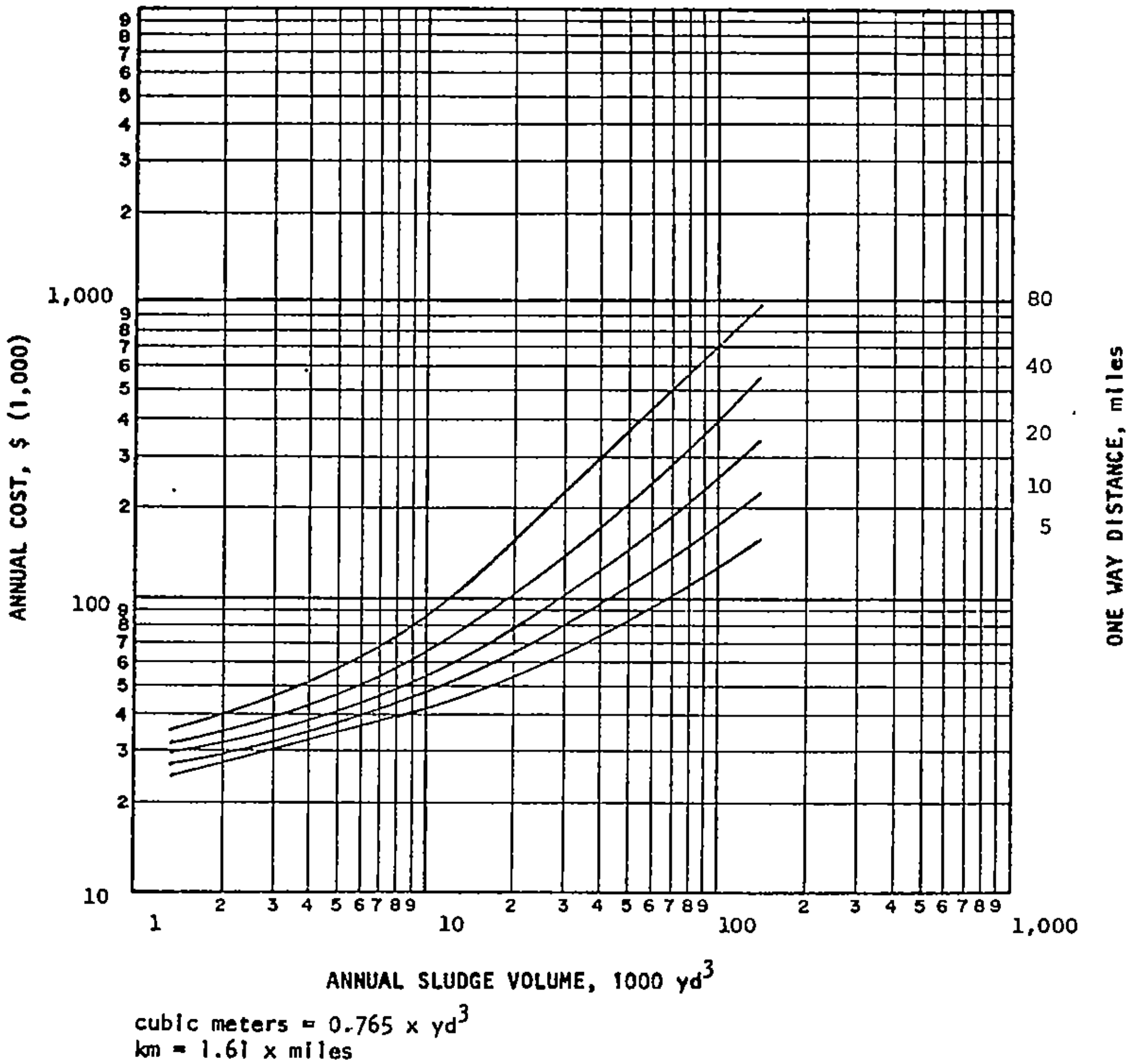


NOTES:

1. Most economical type truck from selection of standard frame or semi trailer mounted bodies; tanks for liquid and dump or ram type for dewatered.
2. Eight hours of trucking operation per day.
3. Full cost at $.60 per gallon.
4. Operating and maintenance labor at $8.00 per hour including fringes.
5. Electric energy at $.02 per kwh.
6. Amortization of truck capital cost over six years at seven percent.
7. Truck O&M cost, excluding fuel and operator, $0.20 to $0.30 per mile depending on type of truck.
8. Truck loading time 30 minutes and unloading time 15 minutes.
9. Truck average speed 25 mph for first 20 miles one way and 35 mph for rest.
10. General and administrative costs 25 percent of total O&M cost.

Figure 25. Truck transport total annual cost with loading & unloading facilities 8 hour operation per day liquid sludge 1976 (71).



NOTES:

1. Most economical type truck from selection of standard frame or semi trailer mounted bodies; tanks for liquid and dump or ram type for dewatered.
2. Eight hours of trucking operation per day.
3. Full cost at $.060 per gallon.
4. Operating and maintenance labor at $8.00 per hour including fringes.
5. Electric energy at $.02 per kwh.
6. Amortization of truck capital cost over six years at seven percent.
7. Truck O&M cost, excluding fuel and operator, $0.20 to $0.30 per mile depending on type of truck.
8. Truck loading time 30 minutes and unloading time 15 minutes.
9. Truck average speed 25 mph for first 20 miles one way and 35 mph for rest.
10. General and administrative costs 25 percent of total O&M cost.

Figure 26. Truck transport total annual cost with loading & unloading facilities 8 hour operation per day dewatered sludge 1976 (71).

season and that lagoon storage would be required for only 10% of the generated sludge volume. Thickened or vacuum filtered sludge would be stored for longer time periods and applied approximately two times per year, in spring and fall. Storage of 40% of the volume was then required. The basis for these costs are given in Figures 27 and 28. Distribution costs were assumed to be a percentage of the transportation costs associated with a site. For haul distances of 32.2km (20mi) or less, distribution costs were estimated to be 25% of the transportation costs and for haul distances of 33-64 km (21-40mi) the distribution costs were estimated to be 12.5% of the transportation costs.

Land requirements were calculated based on 18.9 metric ton/ha/yr (8.5 ton/acre/year) as established in Section VII. These were adjusted to include borders, buffer zones, roads, etc. using a multiplier of 1.4 for acreage less than or equal to 405ha (1000 acres) or 1.1 for larger land requirements. The land costs were based on the assumption that the purchase value of the land is equivalent to its salvage value and the anual cost was equal to the annual interest on the purchase price (5 7/8%). The purchase price of land was estimated to be $3706/ha ($1500/acre) (40). The land preparation costs included clearing, leveling and site preparation. These costs were estimated from Figure 29.

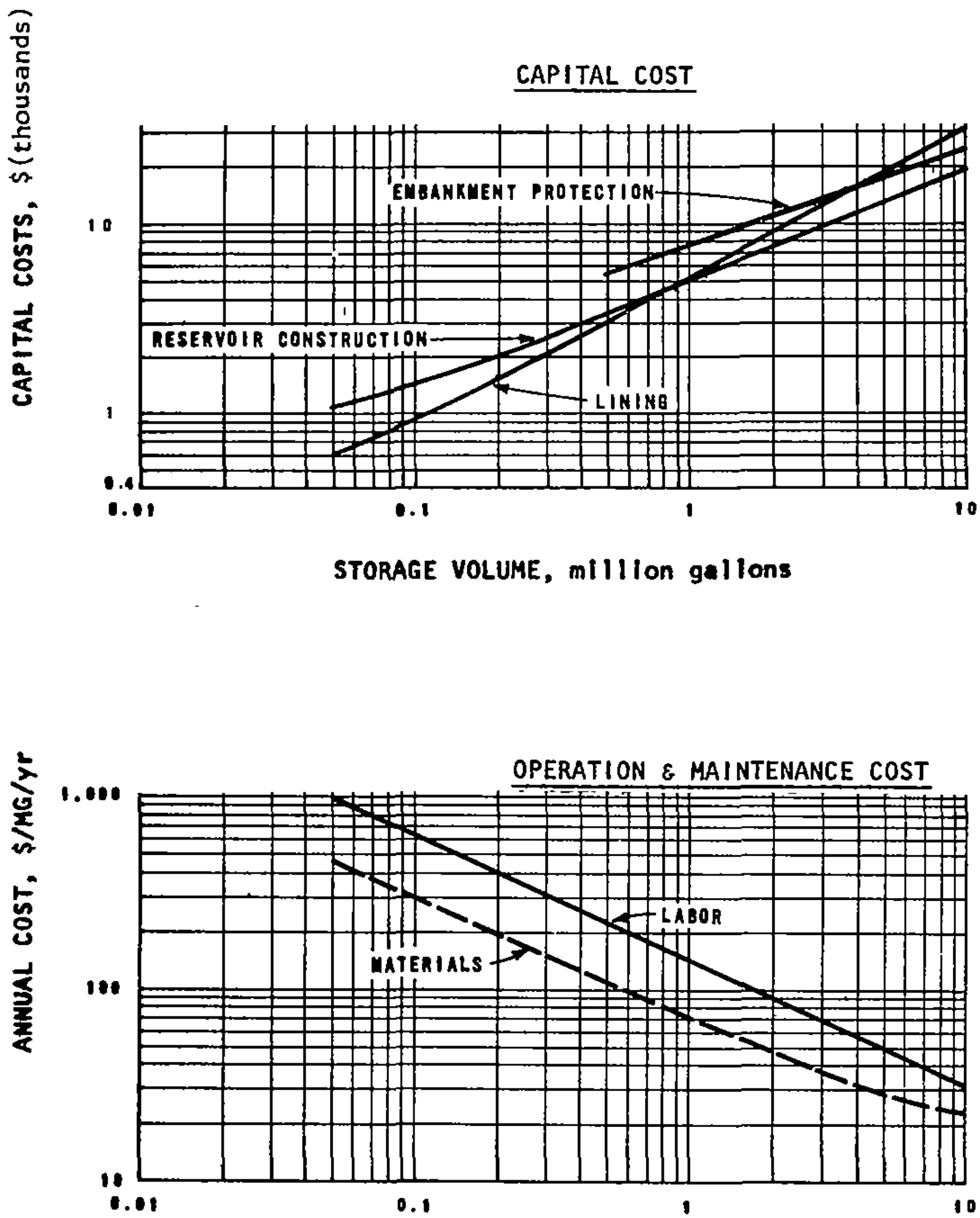
Once all capital and operating costs were estimated based on the various cost curves etc., then these were amortized to establish a total annual cost for the system. The amortization was based on 5 7/8% interest and a 20 year life for all systems.

IMPACT OF SLUDGES PRODUCED BY CSO TREATMENT ON FOUR EXAMPLE CITIES

The potential economic impact of treatment and handling of CSO treatment residuals is considered in this subsection with respect to four example cities. Four actual cities have been chosen to illustrate different CSO treatment sludges and different size systems. The cities which have been evaluated are Milwaukee, Wisconsin; San Francisco, California; Kenosha, Wisconsin; and New Providence, New Jersey.

Extensive analysis involving the various CSO sludge handling alternatives has been performed for the Milwaukee site. The evaluation includes potential costs for bleed/pump-back, treatment at parallel sludge handling facilities, and satellite treatment using several different treatment trains. It is apparent from these analyses and previous discussion, that although bleed/pump-back may be most inexpensive, it is likely to be most impractical. Treatment at parallel facilities at the dry-weather plant is expensive if handled in 120 days and may be impossible due to space limitations. Therefore further evaluation of the potential impact of CSO sludges in other cities was limited to satellite treatment considerations.

The individual evaluation was then divided into several steps. The first step involved estimation of the extent of the CSO problem based on precipitation data, area of the city served by combined sewers, the potential pro-



cubic meters = 3.784 x 10^3 million gallons

Figure 27. Storage (0.05-10 million gallons)(48).

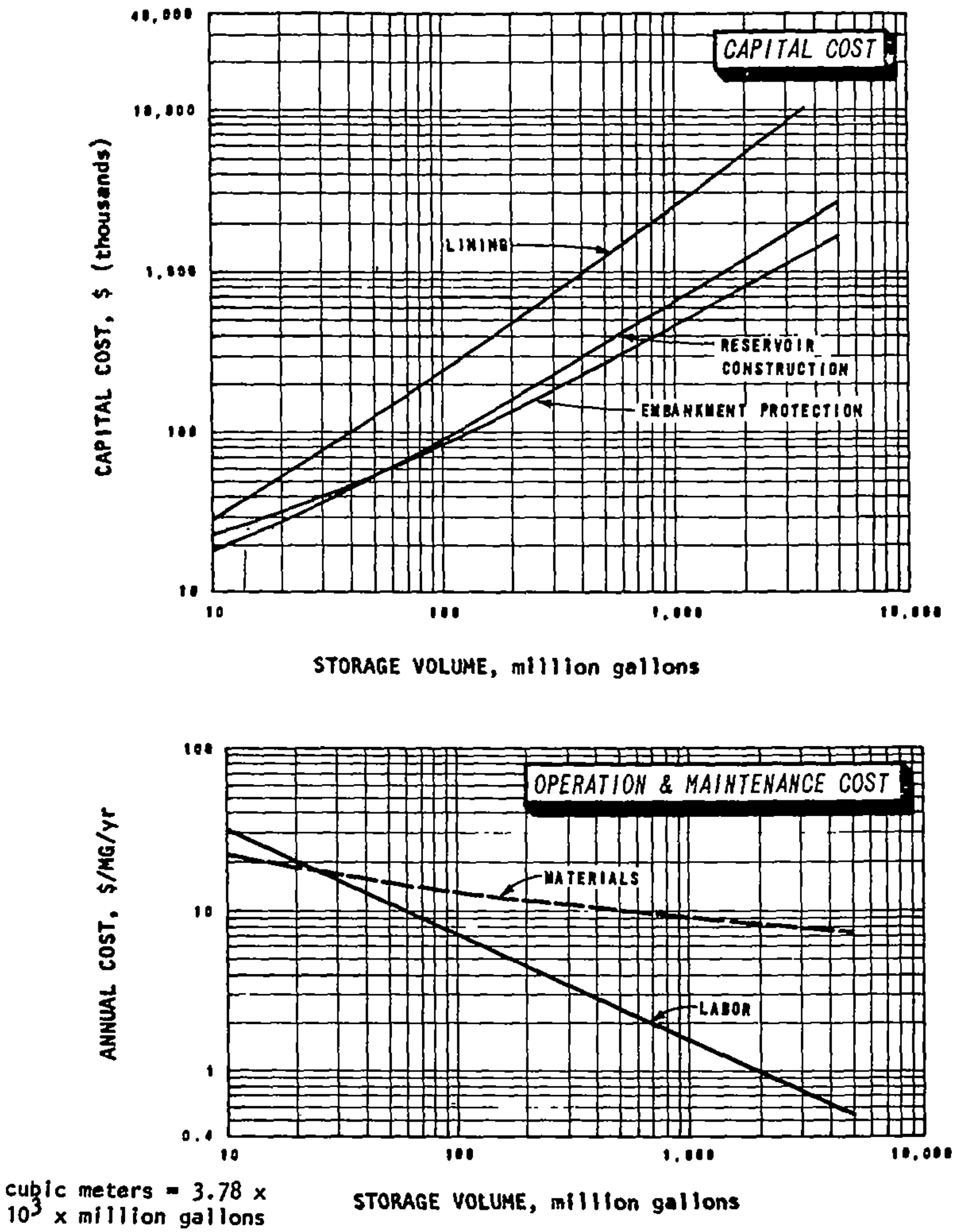
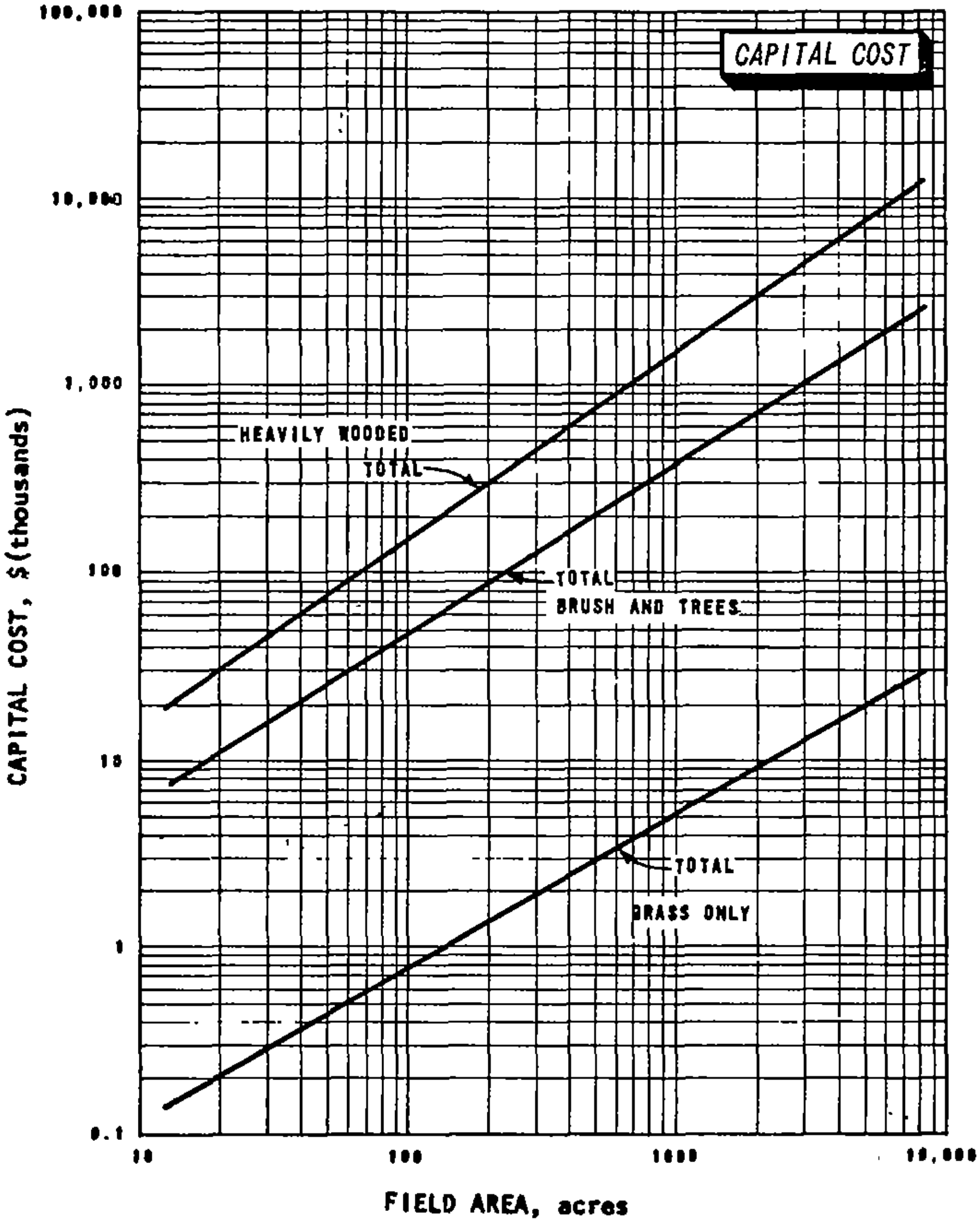


Figure 28. Storage (10-5,000 millions gallons)(48).



hectares = 0.405 x acres

Figure 29. Field preparation - site clearing (48).

cess used for CSO treatment and the characteristics of the sludges produced by the CSO treatment process.

The second step will be to present information on each city's dry-weather sludge handling facilities, including capacities, amount of solids presently being handled, and any excess handling capacity presently available.

Once the necessary information has been developed, the final step will be to assess the impact of the CSO generated solids on the city's present sludge handling and disposal system. The impact will be evaluated on both a physical and economic basis. Rough estimates of what the capital costs will be for constructing new sludge handling facilities at the site of CSO treatment have been developed and are presented in the following discussion.

CSO SLUDGE HANDLING IN MILWAUKEE, WISCONSIN

Evaluation of the various methods of handling CSO sludges in Milwaukee, Wisconsin was completed in depth to illustrate the effect of bleed/pump-back of CSO sludge and sludge handling at parallel sludge facilities and on-site satellite treatment. In Milwaukee, the dry-weather treatment plant is presently at capacity with respect to its sludge handling facilities. This is a common situation for plants serving combined sewer areas since often the treatment plant has reached design capacity and sometimes exceeded it, due to age. Therefore the example provided by Milwaukee is somewhat typical of conditions at treatment plants serving combined sewered areas.

In Milwaukee, the entire drainage area is 25,110 ha (62,000 acres). Of this total, 7,006 ha (17,300 acres) or 28 percent are served by combined sewers. The average annual precipitation for the city is 74.7 cm (29.4 in). If it is assumed that 50 percent of this rainfall accounts for combined sewer overflow, the annual volume of CSO for the city of Milwaukee is 26 million cu m (6,910 MG).

Presently in Milwaukee there is a CSO storage tank demonstration facility. This storage tank is equipped with mixers so that when the contents are bled/pumped-back to the dry-weather treatment plant, it is similar to the raw CSO. However, when the storage tank has its capacity exceeded, the mixers are not operated and the tank functions similar to a sedimentation basin. The impact of CSO sludges on the city of Milwaukee will be based on the assumption that complete CSO treatment is achieved by storing the 26 million cu m (6,910 MG) in storage tanks located in four parts of the city. The supernatant from the tanks will be continuously bled/pumped-back to the dry-weather treatment plant. After bleed/pump-back of the supernatant, a residual settled sludge will remain to be handled and disposed of.

Based on bench scale settling tests (12), it has been found that the sedimentation process will produce a sludge volume equal to 0.9 percent of the CSO volume stored. The resultant sludge will have an average total solids concentration of about 1.7 percent. The sludge characteristics were given in Table 4.

Based on the reported data, Milwaukee can expect an annual CSO volume of 26 million cu m (6,910 MG). Of this total 25.9 x 10^6 cu m (6.8x10^6 MG) would be bled back to the dry-weather plant as supernatant and 2.3 x 10^5 cu m (62 MG) would remain as residual sludge at a concentration of 1.7 percent.

The average raw CSO concentration of suspended solids at the Milwaukee CSO storage facility is 192 mg/l. Storage of all the CSO would mean storage of 5.0 x 10^6 kg (11.0 x 10^6 lbs) of CSO solids. The residual sludge volume of 2.3 x 10^5 cu m (62 MG) would represent 4.0 x 10^6 kg (8.8 x 10^6 lbs) of the solids. The remaining 1.0 x 10^6 kg (2.2 x 10^6 lbs) of solids would be bled back to the dry-weather treatment plant with the 25.9 x 10^6 cu m (6.8 x 10^3 MG) of supernatant. This means a supernatant suspended solids concentration of 40 mg/l.

The metropolitan Milwaukee area is served by two sewage treatment plants, the Jones Island Plant and the South Shore Plant. The Jones Island Plant is the major plant and serves almost all of the city's combined sewer areas and, therefore, will be the subject of analysis. The treatment consists of primary screening followed by the conventional activated sludge process, and chlorination. Plant data indicates that the facility has an average daily flow of 6.5 x 10^5 cu m/day (1.7 x 10^2 MGD) with an average suspended solids concentration of 236 mg/l. This results in 1.5 x 10^5 kg/day (3.4 x 10^5 lb/ day of solids.

The primary sludge is incinerated. The waste activated sludge is gravity thickened, vacuum filtered, and then processed into a commercial fertilizer. The sludge handling capacity at the plant is 199 metric tons/day (220 tons/ day), and the facilities run near capacity at all times.

The use of storage/settling facilities for complete CSO abatement will have two impacts on the dry-weather plant. First, there may be an impact due to bleed/pump-back of the supernatant and, second, there may be a much greater impact from the residual sludges if they are bled/pumped-back.

For complete CSO abatement, the supernatant represents 25.9 x 10^6 cu m (6.8 x 10^3 MG) and 1.0 x 10^6 kg (2.2 x 10^6 lbs) of wet weather solids. On an annual basis, the supernatant volume represents a hydraulic loading increase of 11 percent to the dry-weather plant. The additional solids loading to the dry-weather plant represents an increase of only 2 percent. The design capacity of the Jones Island Plant is 757,000 cu m/day (200 MGD) and it is presently operating at 6.5 x 10^5 cu m/day (1.7 x 10^2 MGD) or 86 percent of capacity. Therefore it should be able to handle the increased flows due to bleed/pump-back of the supernatants from the storage facilities. This assumes a constant yearly bleed/pump-back of 7.1 x 10^4 cu m/day (19 MGD) from the facilities.

Although the solids handling facilities at the dry-weather plant are operating near capacity, the slight solids loading increase of 2 percent due to the supernatants should be manageable without the need for expansion of the facilities. Therefore, the impact of the supernatants on the dry-weather treatment plant will probably be minimal.

The bleed/pump-back of the settled sludge, on the other hand, does not appear to be feasible. The 4.0×10^6 kg (8.8×10^6 lbs) of sludge solids represent a 7 percent increase in solids loading to the dry-weather plant. Since these solids would be fed along with the supernatant, the total solids loading will be increased by 9 percent. Since the solids handling facilities are now operating near capacity, a 9 percent solids increase would probably require construction of new facilities.

In addition to the 9 percent solids loading increase, other considerations seem to rule out bleed/pump-back as a means of handling the CSO generated solids. One factor to be considered is that Milwaukee's waste activated sludge is converted to a commercial fertilizer. Thus, even if the solids handling facilities are adequate for the increased solids loading, the effect of these solids on the fertilizer being produced may be a significant problem. The volatile solids percentage of the CSO sludge is 48.4 percent which is very low when compared to waste activated sludges. This casts doubt on the quality of the CSO solids as a fertilizer material.

The second consideration also relates to the low volatile content of the CSO sludge. As stated previously, the primary sludge at the Jones Island Plant is incinerated. The inclusion of the low volatile CSO solids in the dry weather sludge could greatly reduce the efficiency of the incineration process and a significant amount of auxiliary heat may be required for combustion due to the presence of CSO solids.

A final consideration is the logistics of bleed/pump-back itself which may be difficult to effectively accomplish. The potential accumulation of grit and organics in the sewers could be a problem without sufficient carrying velocity from dry-weather flow.

However, if it is assumed that the CSO sludge can be bled/pumped-back to the treatment plant without problems and that the plant operation will not be adversely affected by the sludge, then a preliminary cost estimate for this approach can be made. There are two potential techniques to consider. One involves holding the sludge and pumping it back over the entire year (365 days) and the other involves approximately 48 hour storage or a 120 day bleed/pump-back period. The difference has a significant effect upon the size of the additional facilities required at the plant.

With the addition of the South Shore Treatment Plant in Milwaukee, the hydraulic loading on the Jones Island facility has been decreased. However, the sludge handling facilities are operating at maximum capacity. Therefore bleed/pump-back of the sludge will require that the sludge handling system including thickeners, incinerators, vacuum filters, sludge dryers and Milorganite bagging be increased in size to handle the excess loading. The operating costs at the plant will also be greater.

Assuming that the sludge is handled through the treatment plant, the solids will increase from 3.6 to 11.4 metric tons/day (4 to 12.6 tons/day). This additional loading will require a significant increase in sludge handling facilities. According to cost estimates prepared from various sources (72, 73), the capital and O & M costs for bleed/pump-back are included in Table 41 for either a 365 or 120 day bleed/pump-back period. As can be seen, costs will range from approximately $1.26 million-$1.56 million annually for CSO sludge treatment using bleed/pump-back.

Table 41 COSTS FOR BLEED/PUMP-BACK-MILWAUKEE

Pump-back Time	120 day	365 day
Capital Costs:		
Storage Tanks	$ 520,000	$1,692,000
Incinerator	117,000	30,000
Pumps	1,360,000	1,360,000
Sludge Handling Equip.	7,082,000	3,376,000
15% Contingency	1,362,000	968,000
Total Capital Cost	10,441,000	7,427,000
Amortized Capital Cost	885,000	629,000
Annual Operation & Maintenance Cost	677,000	635,000
Total Annual Cost	1,562,000	1,264,000

Another approach, given that bleed/pump-back is not feasible due to the difficulty in transport through pipelines, is to haul the sludge to parallel facilities at the dry-weather treatment plant itself. This procedure would involve trucking of the dilute sludge to the treatment plant and placing it directly into the sludge handling facilities. It is assumed, at this plant, that the additional load will not adversely affect the Milorganite operation but it will require additional solids handling equipment. Two approaches are utilized as before. One involves storage and hauling over the complete 365 days and the second involves hauling over a 120 day period. The costs for these procedures are presented in Table 42. It is apparent that due to the transportation costs, that this option is more costly for both time periods than bleed/pump-back.

The third system which can be evaluated involves handling the CSO sludges at the sites of the CSO storage/settling facilities. The CSO facilities will generate 234,670 cu m (62 MG) of sludge at 1.7 percent solids annually. The first step in handling the sludge on site should be lime addition to raise the pH above 12. This should destroy any pathogens present in the sludge and prevent odor problems from developing at the sites. After this the sludge can be gravity thickened and then possibly dewatered. Vacuum filtration should be used because of the large amounts of lime in the sludge. For a number of CSO storage/settling facilities located throughout the city, it may be more economically advantageous to have a mobile unit that could move from site to site rather than vacuum filtration facilities located at each individual site. However, for this evaluation it has been assumed that the sludge has been handled at four sites within the city with each site processing an equal volume of sludge.

Table 42 COSTS OF TREATMENT
AT PARALLEL DRY-WEATHER FACILITIES-MILWAUKEE

Hauling Period	120 day	365 day
Capital Costs:		
Storage	$ 520,000	$1,692,000
Pumping	1,360,000	1,360,000
Sludge Handling Equip.	7,082,000	3,376,000
15% Contingency	1,344,000	964,000
Total Capital Cost	10,306,000	7,392,000
Amortized Capital Cost	873,000	626,000
Annual Operation & Maintenance Cost	977,000	935,000
Total Annual Cost	$1,850,000	$1,561,000

Based on the information available on CSO sludge generated in Milwaukee and the four treatment schemes developed previously, cost estimates for satellite treatment in Milwaukee were developed. The basis of costs and figures presented earlier in this chapter were utilized and the results are presented in Table 43. It can be seen that hauling the stabilized only sludge to a land application site (Alternate 4, Table 43) is extremely expensive due to the transportation costs. These costs indicate that Alternative 3 or lime stabilization followed by gravity thickening and land application may be the most cost effective approach in Milwaukee. High costs of vacuum filtration at several sites indicate that use of this dewatering technique is not cost effective.

A comparison of the annual costs for all three approaches to handling CSO sludge is presented below:

Method 1 - Bleed/Pump-back

120 days - $1,561,000

365 days - $1,264,000

Method 2 - Treatment at Parallel Dry-Weather Facilities

120 days - $1,850,000

365 days - $1,561,000

TABLE 43. COST ESTIMATES FOR CSO SLUDGE HANDLING BY SATELLITE TREATMENT - MILWAUKEE

Alternative Number	Element	Capital Cost $	Operation & maintenance cost	Annual cost
1	Pumping	$1.36x10^6$	$ 55,000	$ 170,000
	Storage	$1.42x10^6$	--	120,000
	Lime Stabilization	$0.426x10^6$	223,000	259,000
	Gravity thickening	$1.193x10^6$	24,000	125,000
	Vacuum filtration	$5.112x10^6$	185,000	617,000
	Transportation	--	--	130,000
	Landfill	$2.272x10^6$	60,000	252,000
	Subtotal			$1,673,000
	15% Contingency			251,000
	TOTAL			$1,924,000
2	Pumping	$1.36x10^6$	$ 55,000	$ 170,000
	Storage	$1.42x10^6$	--	120,000
	Lime Stabilization	$0.426x10^6$	223,000	259,000
	Gravity Thickening	$1.193x10^6$	24,000	125,000
	Vacuum Filtration	$5.112x10^6$	185,000	617,000
	Transportation	--	--	130,000
	Land Application	--	--	86,000
	Subtotal			$1,507,000
	15% Contingency			226,000
	TOTAL			$1,733,000

TABLE 43 (continued).

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
3	Pumping	1.36×10^6	$ 55,000	$ 170,000
	Storage	1.42×10^6	--	120,000
	Lime Stabilization	0.426×10^6	223,000	259,000
	Gravity Thickening	1.193×10^6	24,000	125,000
	Transportation	--	--	490,000
	Land Application	--	--	137,000
	Sub Total			$1,301,000
	15% Contingency			195,000
	TOTAL			$1,496,000
4	Pumping	1.36×10^6	$ 55,000	$ 170,000
	Storage	1.42×10^6	--	120,000
	Lime Stabilization	0.42×10^6	223,000	259,000
	Transportation	--	--	1,400,000
	Land Application	--	--	249,000
	Sub Total			$2,198,000
	15% Contingency			330,000
	TOTAL			$2,528,000

Method 3 - Satellite Treatment (120 days)

Alternative 1 - 1,924,000

Alternative 2 - 1,733,000

Alternative 3 - 1,496,000

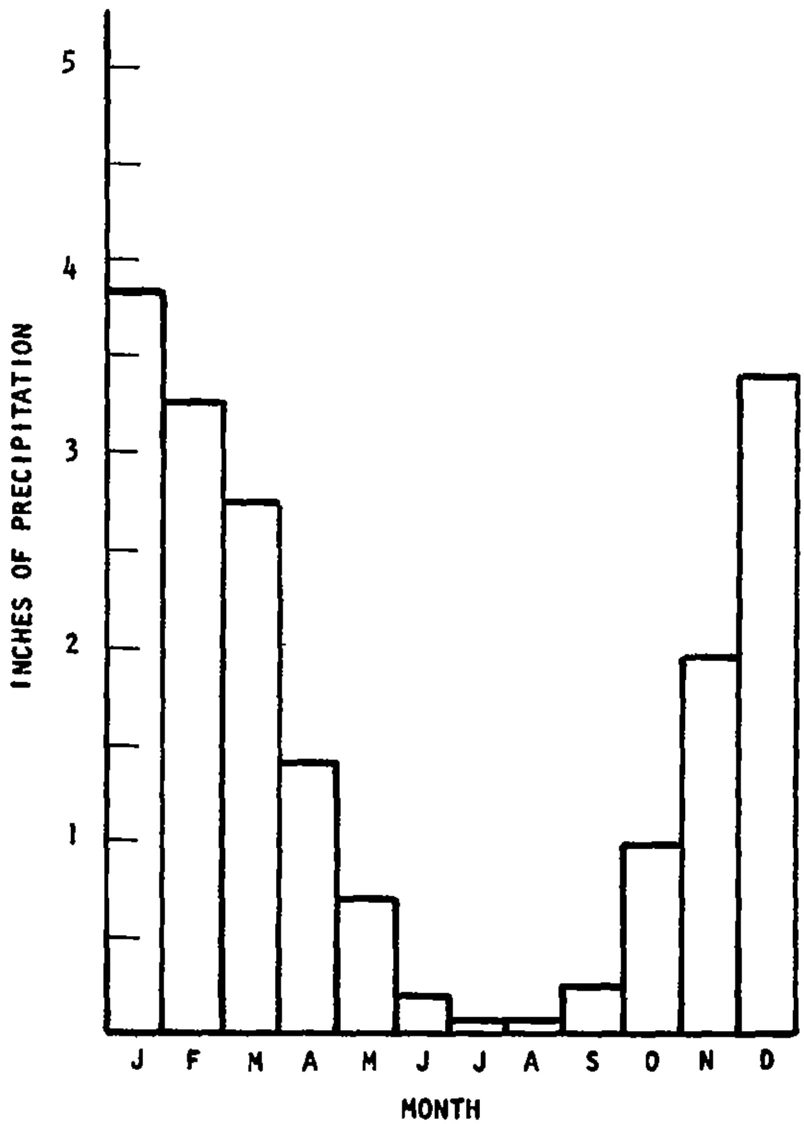
Alternative 4 - 2,528,000

It can be seen that the cost of bleed/pump-back is less than other alternatives when considered over 365 days, but it begins to exceed other alternatives when a shorter bleed/pump-back period is established. Treatment at parallel dry-weather facilities does not offer significant advantages over satellite treatment and when coupled with potential interference in plant operation and space limitations at Jones Island, this method becomes less viable. Finally, the various alternatives chosen for satellite treatment could be utilized without operating problems associated with bleed/pump-back or parallel facilities. The costs are similar to other alternatives presented. Therefore the most cost effective and least problematic approach at this time seems to be satellite treatment using lime stabilization, storage, gravity thickening and land application.

CSO SLUDGE HANDLING IN SAN FRANCISCO, CALIFORNIA

In San Francisco, the entire drainage area of 12,150 ha (30,000 aeres) is served by a combined sewer system. The average annual precipitation for the area is 47.5 cm (18.7 in) and typically occurs on a monthly basis as shown in Figure 30. It can be seen that very little precipitation occurs during the summer months while the majority of the precipitation occurs from November through April. If it is assumed that 50 percent of this rainfall produces combined sewer overflow, the annual volume of CSO for the city of San Francisco is 28.8 million cu m (7,620 MG).

Presently, a dissolved air flotation CSO treatment demonstration unit is located in San Francisco. It has been reported that this unit will produce a sludge volume equal to 0.6 percent of the CSO volume treated. The resultant sludge will have an average total solids content of approximately 2.2 percent. Other pertinent sludge characteristics are presented in Table 5. Since this unit is working in San Francisco and data is available, it will be assumed for this evaluation that all CSO is treated using the dissolved-air flotation process. The sludge data indicates that San Francisco can expect an annual CSO sludge volume of 1.7×10^5 cu m (46 MG) at 2.2 percent solids or 3.9×10^6 kg (8.6×10^6 lbs) of wet weather produced solids that must be handled and disposed of. The metropolitan San Francisco area is served by three separate primary sewage treatment plants with a total design capacity of 1,135,500 cu m/day (300 MGD). The three treatment sites produce approximately 5.0×10^3 cu m/day (1.3 MGD) of sludge at 1.1 percent solids. This results in 54,480 kg/day (120,000 lbs/day) of solids to be handled. The sludge is gravity thickened, anaerobically digested, and vacuum filtered to a solids concentration of about 28 percent before being disposed of in a landfill or used as a soil conditioner. The present solids handling facilities in San Francisco are operating at capacity (12).



NOTE: In. x 2.54 = cm

Figure 30. Typical monthly distribution of precipitation in San Francisco, California (74).

If complete CSO treatment is achieved in the city, the yearly volume of CSO sludge will represent a hydraulic increase of 9.6 percent over the dry-weather sludge volume presently being handled and an 18.8 percent increase on a dry solids basis. The percentages calculated, however, are based on a constant yearly flow of CSO sludge to the sludge handling facilities. Since CSO events are intermittant in nature and will occur with greater frequency during certain times of the year, it would be impossible to space the flow of CSO sludge to the handling facilities over the entire year unless storage facilities are employed. Therefore, the impact of the CSO sludges has also been calculated based on the following assumptions: no storage in the system, a 72 hour period of CSO sludge bleed-back to the handling facilities, and rainfalls of 1.3 and 0.5 cm (0.5 and 0.2 in) over the CSO area.

The 1.3 cm (0.5 in) rainfall over the CSO area will produce 4.6×10^3 cu m (1.2×10^6 gal) of CSO sludge and 1.0×10^5 kg (2.3×10^5 lbs) of CSO solids. Bleeding the residue into the sludge handling facilities over three days results in additional flows of 1.5×10^3 cu m/day (4.1×10^2 MG) and 3.5×10^4 kg/day (7.6×10^4 lbs/day). These flows represent a 31 percent increase in the hydraulic loading and a 61 percent increase in the solids loading. Thus, the impact of the CSO sludges has increased significantly. The 0.5 cm (0.2 in) rainfall over the CSO area will result in a 12 percent increase in the hydraulic loading, and a 24 percent increase in the solids loading over the three day bleed-back period.

Based on the preceeding calculations, it appears that the first consideration in developing a method of handling the CSO sludge problem will be to reduce the impacts caused by the sporadic flows of the CSO itself. This could be achieved by storage of the CSO in conjunction with the CSO treatment facility. Based on the yearly rainfall of 47.5 cm (18.7 in), San Francisco can expect a yearly CSO volume of 28,840,000 cu m (7,620 MG). Year round operation of a CSO treatment facility would require a treatment plant capacity of 79,485 cu m/day (21 MGD).

The storage facility capacity based on the monthly rainfall variations (Figure 30) is calculated on the next page. These calculations indicate a maximum storage capacity of 11.4×10^6 cu m (3.0×10^3 MG) required for the system at the end of March. This value should then be increased to protect against the yearly fluctuations in rainfall amounts.

This volume, of course, would be for one storage facility serving the entire city. Numerous storage facilities could be located throughout the city and they could then feed a number of small CSO treatment facilities or one 79×10^3 cu m/day (21 MGD) central CSO treatment plant.

The treatment of 79×10^3 cu m/day (21 MGD) of CSO using the dissolved-air flotation process would result in the generation of 480 cu m (126,000 gal) per day of sludge at about 2.2 percent solids. Some of the data reported from the San Francisco demonstration system has indicated floated sludge concentrations of only 1000 to 2000 mg/l. The value of 2.2 percent solids for the floated sludge being used is based on samples taken at the demonstration site and the reported values for floated sludge at other sites using the dissolved-air flotation process (12). Based on the 2.2 percent solids, 10,600 kg/day (23,400 lbs/day) of CSO solids will have to be handled and disposed of from the CSO treatment site.

	CSO Volumes 10^6 cu m (MG)	Volume Treated 10^6 cu m (MG)	Difference 10^6 cu m (MG)	Cumulative Storage 10^6 cu m (MG)
November	2.91 (770)	2.38 (630)	+0.53 (+140)	0.53 (140)
December	5.31 (1402)	2.46 (651)	+2.84 (+751)	3.37 (891)
January	5.95 (1573)	2.46 (651)	+3.49 (+922)	6.86 (1813)
February	5.03 (1328)	2.23 (588)	+2.80 (+740)	9.66 (2553)
March	4.23 (1117)	2.46 (651)	+1.76 (+466)	11.43 (3019)
April	2.11 (558)	2.38 (630)	-0.27 (-72)	11.15 (2947)
May	1.06 (281)	2.46 (651)	-1.40 (-370)	9.75 (2577)
June	0.26 (69)	2.38 (630)	-2.12 (-561)	7.63 (2016)
July	0.06 (16)	2.46 (651)	-2.40 (-635)	5.23 (1381)
August	0.06 (16)	2.46 (651)	-2.40 (-635)	2.82 (746)
September	0.40 (106)	2.38 (630)	-1.98 (-524)	0.84 (222)
October	1.45 (383)	2.46 (651)	-1.01 (268)	0

The two available alternatives for handling the CSO sludge are handling at the CSO treatment site or transporting it to the dry-weather plant and handling it with the existing or expanded dry-weather plant facilities. As mentioned previously, the dry-weather sludge handling facilities are operating at capacity and the addition of the CSO sludges would increase the hydraulic loadings by 10 percent and the solids loadings by 19 percent.

The first consideration would be to transport the sludge to the dry-weather treatment plant by bleeding it back to the sewer system after the CSO event is over. However, due to the characteristics of the CSO sludge, the sludge should not be handled with the processes used for the dry-weather plant. The low volatile content of the sludge, 39.2 percent, indicates that digestion would be ineffective. Therefore, if the solids are introduced into the anaerobic digesters, they would increase the solids and hydraulic loadings and may not digest. This would result in reductions in volatile solids destruction and gas production. There is also the possibility that the heavy metals present in the CSO sludge could pose a toxic hazard to the biological life in the digesters.

The dry-weather sludges are usually gravity thickened before they are pumped to the digesters. The CSO sludge produced by the dissolved-air flotation process can be expected to be over 2 percent solids, and, therefore, may not require further thickening. If the CSO sludge is bled back to the dry-weather plant, it will be diluted in the sewer system and, then, would have to be re-thickened at the dry-weather plant. The sludge volumes would also increase the hydraulic loading on the gravity thickeners by 10 percent.

Based on the preceeding discussion, bleed-back of the sludge to the dry-weather plant should not be attempted for the following reasons:

1. necessity to dilute and then re-thicken the solids,
2. introduction of the low volatile solids into the anaerobic digesters will require valuable space and reduce digester efficiency, and
3. the solids may pose toxic hazards to the anaerobic digesters.

By eliminating bleed-back of the CSO solids to the dry-weather plant, the CSO sludge will have to be transported by tank truck if sludge handling is to be achieved at the dry-weather plant. This would require trucking 477 cu m (126,000 gal) of sludge per day. Since the sludge is already thickened it could go directly to the vacuum filtration process. The vacuum filter facilities, of course, would have to be expanded to handle a solids loading increase of 19 percent. After vacuum filtration the CSO sludge cake could be disposed of at the landfill along with the dry weather sludge. The dry-weather plant now trucks approximately 203 cu m (7260 cu ft) of sludge cake per day to the landfill. The CSO sludge, dewatered to 20 percent solids, will increase this amount by 26 percent to 256 cu m/day (9143 cu ft/day).

Because the CSO sludge has not undergone anaerobic digestion, the sludge should be limed to a pH of greater than 12 in order to stabilize it. This could be accomplished just before vacuum filtration. The liming should insure pathogen destruction before the sludge is landfilled (35).

As the previous discussion indicates, however, the applicability of bleed/pump-back or treatment at additional facilities is a questionable procedure, at best. Considering the results of the total cost evaluation presented for Milwaukee, it can be seen that only a small cost benefit can be achieved by implementing these two questionable processes. Therefore, detailed costs have been prepared only for the alternatives with potential for handling CSO sludge generated in San Francisco at six individual sites throughout the city. These costs are included in Table 44 for the four sludge handling schematics previously chosen applicable for CSO sludge treatment. It can be seen from Table 44 that the handling alternative involving lime stabilization, additional thickening and land application of the resultant sludge is anticipated to be most cost effective of those investigated. Further dewatering does not appear to be feasible.

TREATMENT OF CSO SLUDGES IN KENOSHA, WISCONSIN

The entire drainage area for the city of Kenosha is 3850 ha (9507 acres). Of this total, 539 ha (1331 acres) or 14 percent are served by combined sewers. The average annual precipitation for the area is 77.5 cm (30.5 in). If it

TABLE 44. COST ESTIMATES FOR CSO SLUDGE HANDLING BY SATELLITE OPERATION - SAN FRANCISCO

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
1	Pumping	$1.53x10^6$	$ 68,000	$ 197,000
	Storage	$0.588x10^6$	--	50,000
	Lime Stabilization	$0.50x10^6$	92,000	134,000
	Gravity Thickening	$1.45x10^6$	31,000	154,000
	Vacuum Filtration	$7.67x10^6$	212,000	860,000
	Transportation	--	--	120,000
	Landfill	$2.68x10^6$	89,000	316,000
	Sub Total			$1,831,000
	15% Contingency			275,000
	TOTAL			$2,106,000
2	Pumping	$1.53x10^6$	$ 68,000	$ 197,000
	Storage	$0.588x10^6$	--	50,000
	Lime Stabilization	$0.50x10^6$	92,000	134,000
	Gravity Thickening	$1.45x10^6$	31,000	154,000
	Vacuum Filtration	$7.67x10^6$	212,000	860,000
	Transportation	--	--	120,000
	Land Application	--	--	82,000
	Sub Total			$1,596,000
	15% Contingency			239,000
	TOTAL			$1,835,000

TABLE 44 (continued).

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
3	Pumping	1.53×10^6	$ 68,000	$ 197,000
	Storage	0.588×10^6	--	50,000
	Lime Stabilization	0.50×10^6	92,000	134,000
	Gravity Thickening	1.45×10^6	31,000	154,000
	Transportation	--	--	380,000
	Land Application	--	--	118,000
	Sub Total			$1,033,000
	15% Contingency			155,000
	TOTAL			$1,188,000
4	Pumping	1.53×10^6	$ 68,000	$ 197,000
	Storage	0.58×10^6	--	50,000
	Lime Stabilization	0.50×10^6	92,000	134,000
	Transportation	--	--	1,000,000
	Land Application	--	--	194,000
	Sub Total			$1,575,000
	15% Contingency			236,000
	TOTAL			$1,811,000

is assumed that 50 percent of this rainfall accounts for combined sewer overflow, the annual volume of CSO for Kenosha is 2.1×10^6 cu m (550 MG).

In Kenosha, CSO treatment is being achieved at a demonstration project by the use of the contact stabilization process and data is available concerning the treatment of CSO using this process. For this reason, the impact of CSO sludges on the city of Kenosha will be based on complete CSO treatment using contact stabilization.

The combined sewer overflow treatment system in Kenosha is significantly different from those discussed previously because it is located on the same grounds as the existing conventional dry weather treatment plant. In fact, since the system utilizes biological treatment it depends on the dry-weather plant as a source of active biomass. Waste activated sludge from the dry-weather treatment plant is continuously fed through the CSO treatment system stabilization tank, where it has a hydraulic retention time of approximately five days before going on to flotation thickening. When the CSO treatment system is in operation, the contents of the stabilization tank are pumped to a contact tank instead of to thickening.

It has been reported (12) that the Kenosha contact stabilization process will produce a sludge volume equal to 3.5 percent of the CSO volume treated. The resultant sludge will have an average total solids concentration of 0.85 percent. Other characteristics of the sludge were previously presented in Table 6. The sludge data indicates that Kenosha can expect an annual CSO sludge volume of 73.0×10^3 cu m (19 MG) at 0.85 percent solids or 6.2×10^5 kg (1.4×10^6 lbs) of wet weather produced solids that must be handled and disposed of.

The conventional dry weather treatment plant at Kenosha is a 8.7×10^4 cu m/day (23 MGD) activated sludge process. Waste activated sludge, approximately 300 cu m/day (83,000 gpd) at a solids concentration of 1.47 percent or 4.5×10^3 kg/day (10,000 lbs/day) of solids, is flotation thickened to about 5 percent solids concentration before going on to anaerobic digestion. The digested solids are then further dewatered by means of a filter press. The total daily loading on the digesters, primary and waste activated sludge combined, is 190 cu m/day (50,000 gpd) resulting in a dry solids weight of 1.1×10^4 kg/day (2.4×10^4 lbs/day). The filter press is operated at less than capacity and would be able to handle an additional solids load. The digesters, on the other hand, are already at capacity and additional solids loadings would require construction of additional digestion facilities.

The CSO treatment system presently located on the grounds of the Kenosha dry-weather treatment plant has a capacity of 75,700 cu m/day (20 MGD). The average flow rate during system operation has been found to be 6.1×10^4 cu m (16 MGD)(54). Assuming complete CSO treatment is achieved, this means that in an average year the treatment process will be operated 34 1/2 days. Of course, some form of storage will have to be provided in conjunction with the CSO treatment system in order to detain flows in excess of the 75,700 cu m/day (20 MGD) plant capacity.

In the Kenosha area, rainfall usually occurs from mid-March to mid-December, a total of nine months, with snow being the form of precipitation during the other three months. During the period of rain there occurs about 50 CSO events. Based on these assumptions, then, a CSO event can be expected to occur every fifth day. On the average, each event will generate $42x10^3$ cu m (11 MG) of CSO and require 0.7 days of treatment process operation. This, then, allows for 4.3 days of wet weather sludge bleed/pump-back to the dry-weather plant solids handling facilities.

The $42x10^3$ cu m (11 MG) of CSO per storm event will generate 1460 cu m (385,000 gal) of sludge and $12x10^3$ kg ($27x10^3$ lbs) of solids. Feeding this sludge to the dry-weather plant flotation thickening unit over the next 4.3 days results in additional loadings of 340 cu m/day ($90x10^3$ gpd), an increase of 108 percent, and $2.8x10^3$ kg/day ($6.3x10^3$ lb/day), an increase of 63 percent. Apparently a very significant impact can be expected.

The increased solids due to the CSO sludge will also mean an increased solids loading to the anaerobic digesters of 26 percent and a hydraulic increase of 30 percent. This could result in decreased digester efficiency.

Since the CSO treatment process is located at the dry-weather plant, CSO sludge handling can be accomplished on-site. The two available alternatives are to either handle the CSO sludge with separate parallel facilities or with the existing and/or expanded dry-weather plant facilities.

The handling of the Kenosha CSO sludge will require a treatment scheme similar to the dry-weather plant's process: thickening, stabilization, and dewatering. The primary consideration here is that the dry-weather plant's anaerobic digesters are presently operating at capacity, therefore, the use of anaerobic digestion for the CSO sludge would require digester expansion to handle a 30 percent increase in hydraulic loading and a 26 percent increase in solids loading. This construction would be very costly.

It is possible that excess sludge produced by CSO treatment could be stabilized by lime and this process is therefore a viable alternative to anaerobic digestion. The use of lime stabilization also indicates that gravity thickening is most appropriate, rather than flotation thickening, because the lime treatment will greatly enhance the settling characteristics of the sludge.

It is therefore indicated that the CSO sludges should be handled by parallel processes at the dry-weather plant due to the present location of the CSO treatment unit at this point. Final disposal of dry-weather sludge is presently accomplished using land application, which may be most feasible. However, landfill will also be investigated. The same four CSO sludge handling alternatives have been evaluated for the biological sludge from Kenosha and the results are presented in Table 45. The annual costs range from \$205,000-\$462,000 for the various alternatives. As indicated previously, the most feasible approach appears to be lime stabilization and gravity thickening followed by land application at an annual cost of approximately \$205,000.

However, when further consideration is given to the specific circumstances at

TABLE 45. COST ESTIMATES FOR CSO SLUDGE HANDLING BY SATELLITE TREATMENT-KENOSHA

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
1	Pumping	0.28×10^6	$12,000	$ 36,000
	Storage	0.139×10^6	--	12,000
	Lime Stabilization	0.085×10^6	14,000	15,000
	Gravity Thickening	0.256×10^6	5,000	27,000
	Vacuum Filtration	1.28×10^6	38,000	146,000
	Transportation	--	--	16,000
	Landfill	0.50×10^6	29,000	71,000
	Sub Total			$323,000
	15% Contingency			48,000
	TOTAL			$371,000
2	Pumping	0.284×10^6	$12,000	$ 36,000
	Storage	0.139×10^6	--	12,000
	Lime Stabilization	0.085×10^6	14,000	15,000
	Gravity Thickening	0.256×10^6	5,000	27,000
	Vacuum Filtration	1.28×10^6	38,000	146,000
	Transportation	--	--	16,000
	Land Application	--	--	16,000
	Sub Total			$268,000
	15% Contingency			40,000
	TOTAL			$308,000

TABLE 45 (continued).

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
3	Pumping	0.284×10^6	$12,000	$ 36,000
	Storage	0.139×10^6	--	12,000
	Lime Stabilization	0.085×10^6	14,000	15,000
	Gravity Thickening	0.256×10^6	5,000	27,000
	Transportation	--	--	60,000
	Land Application	--	--	28,000
	Sub Total			$178,000
	15% Contingency			27,000
	TOTAL			$205,000
4	Pumping	0.284×10^6	$12,000	$ 36,000
	Storage	0.139×10^6	--	12,000
	Lime Stabilization	0.085×10^6	14,000	15,000
	Transportation	--	--	260,000
	Land Application	--	--	79,000
	Sub Total			$402,000
	15% Contingency			60,000
	TOTAL			$462,000

Kenosha, other variables must be discussed. One aspect is that the land application costs could be reduced since the city of Kenosha is presently disposing of their dry-weather treatment plant sludge on private farms and if this arrangement could be continued for the additional CSO sludge, there would be no capital expense for land disposal in alternatives 2-4. The second factor is that, as discussed previously, the dry-weather plant's pressure filter has available, enough additional capacity to handle the CSO sludge. For the estimates in Table 45, a complete handling and disposal system was set up to handle all the CSO sludge flows assuming no additional capacities being available in the dry-weather plant. Vacuum filtration was selected as the dewatering method because it was felt that this method would be most amenable for dewatering the heavily limed sludge resulting from the lime stabilization process. For the specific case of Kenosha, investigations should be conducted to determine the ability to pressure filter the lime sludge. If these tests show that pressure filtration will produce satisfactory results, then, for Kenosha, the capital costs of vacuum filtration could be eliminated from alternatives No. 1 and 2.

With these factors considered, the annual costs for alternatives 1 through 4 become:

	Old	New
Alt. 1	$371,000	$247,000
Alt. 2	308,000	171,000
Alt. 3	205,000	193,000
Alt. 4	462,000	456,900

Therefore, since additional dewatering capacity is available, this process, with land application using the existing dry-weather sludge disposal procedure, seems to be very economically attractive for Kenosha.

WET WEATHER SLUDGE HANDLING FOR NEW PROVIDENCE, NEW JERSEY

In New Providence, the entire drainage area for the sewage system is 985 ha (2432 acres). There are no areas serviced by combined sewers but during periods of wet weather, high flows are experienced because of infiltration into the sanitary sewers. If these high flows are treated, New Providence will experience increased solids production due to wet weather conditions even though there are actually no combined sewer overflows.

The average annual precipitation for the area is 109.0 cm (42.9 in). It has been reported in the literature (9) that about 10 percent of this rainfall can be expected to appear as increased flow in infiltrated sanitary sewers. Using these values, then, the annual volume of increased flow due to wet weather for the city of New Providence is 1.1×10^6 cu m (280 MG).

There is a demonstration treatment system employing the trickling filter process in New Providence. The trickling filters are used to treat both the dry-weather flows and wet weather flows. The trickling filters are operated in series during dry weather and switched to parallel operation for high flow rates generated by wet weather. The trickling filter removal efficiency data is available but the necessary sludge production data is not. Therefore the sludge production data required will be estimated based on the pollutant removal efficiencies. The sludge estimates will then be used to assess the impact of wet weather sludges on the city of New Providence.

The following values have been reported (9) for the trickling filter process:

Dry Weather		
Average Flow	2,044 $\frac{\text{cu m}}{\text{day}}$	(0.54 MGD)
SS (influent)		154 mg/l
SS (primary effluent)		86 mg/l
SS (final effluent)		20 mg/l
BOD (primary effluent)		104 mg/l
BOD (final effluent)		23 mg/l
Wet Weather		
Average Flow	14,989 $\frac{\text{cu m}}{\text{day}}$	(3.96 MGD)
SS (influent)		109 mg/l
SS (primary effluent)		64 mg/l
SS (final effluent)		36 mg/l
BOD (primary effluent)		86 mg/l
BOD (final effluent)		39 mg/l

Based on the suspended solids removals achieved by primary sedimentation, 140 kg/day (300 lbs/day) of sludge solids can be expected during dry weather and 680 kg/day (1500 lbs/day) during wet weather. Using a primary sludge concentration of 5.5 percent solids, this results in a rate of (2.5 cu m/day) (670 gal/day) during dry weather and 12 cu m/day (3000 gal/day) during wet weather.

The production of secondary sludge is based on suspended solids removal and the production of 0.5 kg(lb) of solids per kg(lb) of BOD removed. During dry weather, the sludge solids production by secondary treatment will be 220 kg/day (480 lb/day) and 770 kg/day (1700 lbs/day) during wet weather. It has been reported that trickling filter sludges will vary from 5 to 10 percent solids depending on the time they are held in the filter (25). For this reason, it is estimated that the secondary sludge will be 7 percent solids during dry weather (low flow) and 5 percent solids during wet weather (high flow). These values result in the production of 3 cu m/day (800 gal/day) of secondary sludge during dry weather and 15 cu m/day (4000 gal/day) of secondary sludge during wet weather. Combining the primary and secondary sludges means the trickling filter will produce 6 cu m/day

(1600 gal/day) of sludge at 6.3 percent solids during dry weather and 28 cu m/day (6200 gal/day) of sludge at 5.2 percent solids during wet weather. The wet weather value represents 0.2 percent of the wet weather flow volume treated. Some of the other sludge characteristics based on samples taken at the trickling filter site were given in Table 6 (12).

For the annual wet weather volume of 1.1×10^6 cu m (280 MG), New Providence can expect an excess sludge volume of 2.1×10^3 cu m (5.6×10^5 gal.) at 5.2 percent solids or 1.1×10^5 kg (2.5×10^5 lb) of wet weather produced solids that must be disposed of.

As mentioned previously, the trickling filter operation also serves the city of New Providence during dry weather. During dry weather the plant treats an average flow of 2×10^3 cu m/day (0.5 MGD) and produces a 6.0 cu m/day (1600 gal/day) of sludge, primary and secondary, at 6.3 percent solids or 350 kg/day (770 lbs/day) of solids. There are no sludge handling facilities at the trickling filter plant. The solids settling in the secondary clarifier are pumped to the primary sedimentation tank where they settle out with the primary solids. This combined sludge is then drained to a sewer which flows to a larger sewage treatment plant downstream. Apparently the downstream treatment plant has the capacity to remove and handle the solids produced at the New Providence facility; and since the New Providence plant handles the entire wet weather flow, no appreciable increase in flow will occur in the future. Therefore, the bleed/pump-back of both dry weather and wet weather sludges from the New Providence facility to the downstream plant appears to be functioning as planned and will continue to be used in the future. In this case, then, there is no impact due to wet weather conditions in the sanitary sewers.

The impact of the wet weather generated solids would be great, however, if the plant were to construct sludge handling facilities. As presented previously, during dry weather the trickling filter plant can be expected to generate 2.5 cu m/day (550 gal./day) of primary sludge at 5.5 percent solids and 3 cu m/day (660 gal./day) of secondary sludge at 7 percent solids. Combining the two sludges gives 6 cu m/day (1600 gal./day) at 6.3 percent solids or 350 kg/day (770 lbs/day) of dry solids.

Any new sludge handling facilities must take into consideration the volumes of sludge generated by wet weather. On an annual basis, wet weather flows will generate a sludge volume of 2.1×10^3 cu m (5.6×10^5 gal.) (primary plus secondary) at approximately 5.2 percent solids or 1.1×10^5 kg (2.5×10^5 lbs) of solids. If these sludge volumes can be bled/pumped-back to the sludge handling facilities over an entire year, the additional loadings would be 6 cu m/day (1600 gal./day), a 100 percent increase over the dry weather flow, and 300 kg/day (660 lb/day), an 86 percent increase over dry weather.

If bleed/pump-back of the wet weather sludge is not achieved over the entire year, the impacts of the sludge will be much greater. The reported daily dry weather flow is 2×10^3 cu m/day (0.5 MGD) while during wet weather conditions the average flow is 15×10^3 cu m/day (4 MGD). This wet weather flow will generate a sludge flow of 28 cu m/day (7.3×10^3 gal./day) and 1.4×10^3 kg/day (3.1×10^3 lb/day). These flow rates are 492 and 406 percent, respectively, above the daily dry weather flow rates.

Thus, even though the city of New Providence does not have a combined sewer system, the impact of wet weather generated solids in the sanitary sewer could be significant. If sludge handling facilities were to be constructed, the wet weather flows would dictate capabilities 2 to 4 times greater than those that would be required based on the dry weather flow rates.

Since there are no available sludge handling facilities at the New Providence site, the same sludge handling schemes were evaluated with respect to the generated volume of wet weather sludge. The costs were developed as before and based on a sludge volume of 36 cu m/day (9.4×10^3 gpd) at solids concentration of 5.2 percent. Therefore the only applicable alternatives involved hauling the stabilized sludge directly to a land application site or dewatering followed by landfill or land application. The cost estimates are included in Table 46. It is indicated that stabilization followed by direct land application of the sludge is the most cost effective approach for the New Providence sludge handling. This alternative provides a significant cost advantage over the other methods, although it is readily apparent that any attempt at on-site sludge handling is costly.

ECONOMIC IMPACT OF NATIONWIDE HANDLING AND DISPOSAL OF CSO TREATMENT SLUDGES

General

This evaluation involved developing an approximation of the economic impact of handling CSO treatment residuals across the country. In order to accomplish this task, the cities containing CSO areas were statistically evaluated. Four specific areas were evaluated for two types of CSO treatment methods (dissolved air flotation and contact stabilization). The same four sludge handling schematics as previously indicated were developed for both types of sludges. All economic data was based on the same cost criteria as presented previously.

Basis of Evaluation

There were several aspects involved in developing the necessary information for hypothetical cities across the United States. The first involved choice of CSO areas for evaluation. The next involved establishing both the sludge volume and characteristics so that the process equipment could be properly sized.

To select the city size, the area served by combined sewerage systems in urban United States was obtained (75) and analyzed. The available data consisted of combined sewerage areas serving the fifty states and Washington, D.C. and more specifically included a tabulation of the combined sewerage areas serving the urbanized areas (cities) of the country. A total of 248 urbanized areas were covered with the combined sewerage areas ranging from none to about 205,000 acres. Of the 248 urbanized areas for which data was available 128 of them were not served by combined sewerage systems. The remaining 120 urbanized areas had areas served by combined sewers ranging from 40.5 - 83,025

TABLE 46. COST ESTIMATES FOR CSO SLUDGE HANDLING BY SATELLITE TREATMENT-NEW PROVIDENCE

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
1	Pumping	0.12×10^6	\$ 4,000	\$ 14,000
	Storage	0.019×10^6	--	2,000
	Lime Stabilization	0.028×10^6	2,000	4,000
	Gravity Thickening	N/A	N/A	--
	Vacuum Filtration	0.618×10^6	12,000	64,000
	Transportation	--	--	27,000
	Landfill	0.128×10^6	11,000	22,000
	Sub Total			\$133,000
	15% Contingency			20,000
	TOTAL			\$153,000
2	Pumping	0.12×10^6	\$ 4,000	\$ 14,000
	Storage	0.019×10^6	--	2,000
	Lime Stabilization	0.028×10^6	2,000	4,000
	Gravity Thickening	N/A	N/A	--
	Vacuum Filtration	0.610×10^6	12,000	64,000
	Transportation	--	--	27,000
	Land Application	--	--	9,000
	Sub Total			\$120,000
	15% Contingency			18,000
	TOTAL			\$138,000

TABLE 46 (continued)

Alternative Number	Element	Capital Cost $	Operation & Maintenance Cost	Annual Cost
3	Pumping	--	--	--
N/A	Storage	--	--	--
	Lime Stabilization	--	--	--
	Gravity Thickening	--	--	--
	Transportation	--	--	--
	Land Application	--	--	--
	Sub Total			
	15% Contingency			
	TOTAL			N/A
4	Pumping	0.12×10^6	$ 4,000	$14,000
	Storage	0.019×10^6	--	2,000
	Lime Stabilization	0.028×10^6	2,000	4,000
	Transportation	--	--	35,000
	Land Application	--	--	27,000
	Sub Total			$82,000
	15% Contingency			12,000
	TOTAL			$94,000

ha (100-205,000 acres). The combined sewer area data for the 120 urbanized areas noted above were examined and the following conclusions drawn:

1. The mean combined sewer acreage served was 2309 ha (5700 acres).

2. As mentioned previously, the areas served by combined sewers ranged from 40.5 - 82,025 ha (100-205,000 acres). The following further breakdowns were observed:

   a. Fifteen cities (about 12.5%) had combined sewer areas serving less than 40.5 ha (1000 acres) each.

   b. Fifty-seven cities (about 47.5%) had combined sewer areas serving between 405-4050 ha (1000-10,000 acres) each.

   c. Forty-two cities (about 35%) had combined sewer areas serving between 4050 and 16,200 ha (10,000 and 40,000 acres) each.

   d. Only six cities (about 5%) had combined sewer areas greater than 20,250 ha (50,000 acres) each (San Francisco, CA; Cincinnati, OH; New York, NY; St. Louis, MO; Detroit, MI; and Chicago, IL).

From this information it was established that four example areas could be chosen and representative costs established. An area in each range was used as follows:

a. 12.5% - 0-405 ha (0-1000 acres) CSO area choice: 203 ha (500 acres)

b. 47.5% - 405-4050 ha (1001-10,000 acres) CSO area choice: 2307 ha (5700 acres)

c. 35% - 4050-16,200 ha (10,001-40,000 acres) CSO area choice: 10,118 ha (25,000 acres)

d. 5% - >16,200 ha (>40,000 acres) CSO area choice: 24,300 (60,000 acres)

Once the size of the affected area was established, further assumptions were made regarding the volume of CSO sludge generated. Two types of CSO treatment sludges were considered to allow a range of costs due to varying residue characteristics. One type was biological and contact stabilization sludge was considered and the second type was physical/chemical so dissolved air flotation sludge was evaluated. The criteria listed in Table 47 were then applied to establish CSO sludge flow rates and characteristics.

Economic Results

Each of the CSO areas and resultant sludges were then evaluated with regard to the costs for utilizing one of the four sludge handling alternatives:

Alternative 1. Lime Stabilization → Gravity Thickening → Vacuum Filtration → Landfill
2. Lime Stabilization → Gravity Thickening → Vacuum Filtration → Land Application
3. Lime Stabilization → Gravity Thickening → Land Application
4. Lime Stabilization → Land Application

Table 47 ASSUMPTIONS FOR COST CALCULATIONS

CSO Volume

1. 50% of rainfall is CSO
2. Average rainfall is 0.914m/year (36"/year)
3. 60 storm events occur per year

CSO Sludge - Biological

1. 3.5% of CSO volume = sludge volume
2. Solids concentration is 10,000 mg/l

CSO Sludge - Physical/Chemical

1. 0.6% of CSO volume - sludge volume
2. Solids concentration is 27,500 mg/l

The results are presented in detail for each of the chosen CSO areas in Tables 48-51. A comparison of the cost ranges for the city size is summarized in Tables 52 and 53. It can be seen that the cost for treatment of CSO residuals can vary significantly depending upon the type of CSO treatment used, the sludge handling schematic and the total volume of CSO to be treated. The overall annual cost ranges from \$139/ha-\$1403/ha (\$56-\$660/acre) of CSO served area. When it is recalled that there are 1.2×10^6 ha (3.0×10^6 acres) of area served by combined sewers throughout the country, the economic impact of treating CSO sludges nationwide could range from \$169,000,000 - \$1,720,000,000 annually.

If initial capital costs are evaluated, as indicated in Table 53, this first expense ranges from \$447-\$10,173/ha (\$181-4120/acre). These capital costs assume an initial expenditure for the land which will be recovered when the land is sold. When considering the nationwide impact with respect to initial capital costs, this could range from $\$548 \times 10^6$ - $\$12.5 \times 10^9$ to provide sludge handling and disposal for all treatment residues.

TABLE 48. COST ESTIMATES FOR 500 ACRE CSO AREA

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
1	Pumping	$ 25,000	$ 19,000
	Storage	8,000	13,000
	Lime Stabilization	12,000	6,000
	Gravity Thickening	18,000	13,000
	Vacuum Filtration	108,000	74,000
	Transportation	31,000	25,000
	Landfill	44,000	27,000
	Sub Total	$246,000	$177,000
	15% Contingency	37,000	27,000
	TOTAL	$283,000	$204,000
2	Pumping	$ 25,000	$ 19,000
	Storage	8,000	13,000
	Lime Stabilization	12,000	6,000
	Gravity Thickening	18,000	13,000
	Vacuum Filtration	108,000	74,000
	Transportation	31,000	25,000
	Land Application	19,000	9,000
	Sub Total	$221,000	$159,000
	15% Contingency	33,000	24,000
	TOTAL	$254,000	$183,000

acres x 0.405 = ha

TABLE 48 (continued).

Alternative Number	Element	Annual Cost Biological Treatment	Annual Cost Dissolved-Air Flotation Treatment
3	Pumping	$ 25,000	$ 19,000
	Storage	8,000	13,000
	Lime Stabilization	12,000	6,000
	Gravity Thickening	18,000	13,000
	Transportation	42,000	30,000
	Land Application	182,000	11,000
	Sub Total	$287,000	$ 92,000
	15% Contingency	43,000	14,000
	TOTAL	$330,000	$106,000
4	Pumping	$ 25,000	$ 19,000
	Storage	8,000	13,000
	Lime Stabilization	12,000	6,000
	Transportation	140,000	40,000
	Land Application	43,000	13,000
	Sub Total	$231,000	$ 91,000
	15% Contingency	35,000	14,000
	TOTAL	$266,000	$105,000

acres x 0.405 = ha

TABLE 49. COST ESTIMATES FOR 5700 ACRE CSO AREA

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
1	Pumping	$ 104,000	$ 78,000
	Storage	51,000	17,000
	Lime Stabilization	108,000	58,000
	Gravity Thickening	102,000	54,000
	Vacuum Filtration	375,000	229,000
	Transportation	90,000	38,000
	Landfill	247,000	100,000
	Sub Total	$1,077,000	$574,000
	15% Contingency	162,000	86,000
	TOTAL	$1,239,000	$660,000
2	Pumping	$ 104,000	$ 78,000
	Storage	51,000	17,000
	Lime Stabilization	108,000	58,000
	Gravity Thickening	102,000	54,000
	Vacuum Filtration	375,000	229,000
	Transportation	90,000	38,000
	Land Application	87,000	39,000
	Sub Total	$ 917,000	$513,000
	15% Contingency	138,000	77,000
	TOTAL	$1,055,000	$590,000

acres x 0.405 = ha

TABLE 49 (continued).

Alternative Number	Element	Annual cost	
		Biological Treatment	Dissolved-Air Flotation Treatment
3	Pumping	$ 104,000	$ 78,000
	Storage	51,000	17,000
	Lime Stabilization	108,000	58,000
	Gravity Thickening	102,000	54,000
	Transportation	375,000	60,000
	Land Application	140,000	46,000
	Sub Total	$ 880,000	$313,000
	15% Contingency	132,000	47,000
	TOTAL	$1,012,000	$360,000
4	Pumping	$ 104,000	$ 78,000
	Storage	51,000	17,000
	Lime Stabilization	108,000	58,000
	Transportation	1,100,000	240,000
	Land Application	346,000	346,000
	Sub Total	$1,709,000	$739,000
	15% Contingency	256,000	110,000
	TOTAL	$1,965,000	$849,000

acres x 0.405 = ha

TABLE 50. COST ESTIMATE FOR 25000 ACRE CSO AREA

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
1	Pumping	$ 322,000	$ 186,000
	Storage	141,000	56,000
	Lime Stabilization	451,000	244,000
	Gravity Thickening	354,000	209,000
	Vacuum Filtration	1,025,000	731,000
	Transportation	450,000	100,000
	Landfill	432,000	474,000
	Sub Total	$3,175,000	$2,000,000
	15% Contingency	476,000	300,000
	TOTAL	$3,651,000	$2,300,000
2	Pumping	$ 322,000	$ 186,000
	Storage	141,000	56,000
	Lime Stabilization	451,000	244,000
	Gravity Thickening	354,000	209,000
	Vacuum Filtration	1,025,000	731,000
	Transportation	450,000	100,000
	Land Application	276,000	141,000
	Sub Total	$3,019,000	$1,667,000
	15% Contingency	453,000	250,000
	TOTAL	$3,472,000	$1,917,000

acres x 0.405 = ha

TABLE 50 (continued)

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
3	Pumping	$ 322,000	$ 186,000
	Storage	141,000	56,000
	Lime Stabilization	451,000	244,000
	Gravity Thickening	354,000	209,000
	Transportation	1,800,000	1,000,000
	Land Application	456,000	258,000
	Sub Total	$3,524,000	$1,953,000
	15% Contingency	529,000	293,000
	TOTAL	$4,053,000	$2,246,000
4	Pumping	$ 322,000	$ 186,000
	Storage	141,000	56,000
	Lime Stabilization	451,000	244,000
	Transportation	7,000,000	1,700,000
	Land Application	1,111,000	346,000
	Sub Total	$ 9,025,000	$2,532,000
	15% Contingency	1,354,000	380,000
	TOTAL	$10,379,000	$2,912,000

acres x 0.405 = ha

TABLE 51. COST ESTIMATES FOR 60,000 ACRE CSO AREA

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
1	Pumping	$ 287,000	$ 600,000
	Storage	328,000	126,000
	Lime Stabilization	1,056,000	209,000
	Gravity Thickening	630,000	832,000
	Vacuum Filtration	2,199,000	941,000
	Transportation	900,000	190,000
	Landfill	1,572,000	1,015,000
	Sub Total	$6,972,000	$3,913,000
	15% Contingency	1,046,000	587,000
	TOTAL	$8,018,000	$4,500,000
2	Pumping	$ 287,000	$ 600,000
	Storage	328,000	126,000
	Lime Stabilization	1,056,000	209,000
	Gravity Thickening	630,000	832,000
	Vacuum Filtration	2,199,000	941,000
	Transportation	900,000	190,000
	Land Application	626,000	265,000
	Sub Total	$6,026,000	$3,163,000
	15% Contingency	904,000	474,000
	TOTAL	$6,930,000	$3,637,000

acres x 0.405 = ha

TABLE 51 (continued)

Alternative Number	Element	Annual cost: Biological Treatment	Annual cost: Dissolved-Air Flotation Treatment
3	Pumping	$ 287,000	$ 600,000
	Storage	328,000	126,000
	Lime Stabilization	1,056,000	209,000
	Gravity Thickening	630,000	832,000
	Transportation	4,000,000	780,000
	Land Application	1,043,000	347,000
	Sub Total	$7,344,000	$2,894,000
	15% Contingency	1,102,000	434,000
	TOTAL	$8,446,000	$3,328,000
4	Pumping	$ 287,000	$ 600,000
	Storage	328,000	126,000
	Lime Stabilization	1,056,000	209,000
	Transportation	20,000,000	3,400,000
	Land Application	1,043,000	677,000
	Sub Total	$22,714,000	$5,012,000
	15% Contingency	3,407,000	752,000
	TOTAL	$26,121,000	$5,764,000

acres x 0.405 = ha